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The effects of water addition on the threshold speed, gamma and net density of Du Pont Lino-Writ 5 direct recording paper

Robert H. Renner

Stanley N. Stein

THE EFFECTS OF WATER ADDITION ON THE THRESHOLD SPEED, GAMMA AND NET DENSITY OF DU PONT LINO-WRIT 5 DIRECT RECORDING PAPER.

by

Robert H. Renner and Stanley N. Stein

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Abstract

The effects on speed, gamma and net density of Du Pont Lino-Writ 5 paper, by the addition of water prior to the initial exposure and amplification exposure separately and in combination, was investigated. The effects on speed and net density of Kodak Polycontrast paper by water addition prior to exposure were also explored for comparsion purposes.

A statistically significant decrease in the average value of speed and a significant increase in the average value of net density was observed when Lino-Writ paper was moistened. The addition of moisture gave no evidence of having an effect on the average value of gamma. Moisture did not significantly ~~effect~~ affect either the speed or net density of Kodak Polycontrast paper.

Introduction

Recent developments in modern engineering have brought about a need for a photographic material to record high speed traces on direct writing oscillographs and to give rapid image access with an avoidance of chemical processing. Such a need has been partially fulfilled by a new class of printing out emulsions in high speed direct recording papers. These papers can produce, when used with a direct-writing oscillograph having a high-intensity exposing light, a latent image at writing speeds in excess of 40,000 in/sec.[1] Such an image is made visible not by chemical processing but by an amplification exposure. This amplification exposure, usually to a source rich in ultraviolet, must be greater by a factor of 20,000.[2]

The work of Luppo-Cramer,[3] Debot[4] and Berg[5] have shown that while generally the intense initial exposure favors internal latent image formation, the low intensity amplification exposure forms primarily surface latent image. Hunt of Du Pont using techniques described by Dyba and Smith[6] and Stevens[7] obtained results which confirmed this conclusion.[8]

High speed direct recording papers take advantage of these facts to form little or no new internal (i.e. in grains not exposed by high intensity) latent image upon amplification exposure, but do form surface latent image on grains ? which did not receive the high intensity initial exposure. These surface latent images apparently inhibit or prevent the formation of internal latnet image. As a result the background is desensitized ? and only the grains which were originally exposed become blackened to form the image by continued formation of internal print-out image.[9] Both the formation of the latent image and its development by light without complete loss through darkening of the background is associated with the extreme low-intensity reciprocity law failure of these emulsions.[10]

The sensitivity of these emulsions can be increased by heating the paper during amplification. The mechanism of the temperature effects is believed by Hunt to operate through the destruction of latent image fog centers. The result of this is that the internal latent image formed by the first high intensity exposure is made visible, while the image centers formed durning the secondary exposure are not stable enough at the elevated temperature to become amplified to a visible image.[11] Jacobs describes a method of heating the paper during amplification to provide enough energy to allow an exposure time of a fraction of a second.[12] Obtaining the image rapidly by the use of such a method however is very often impossible or highly impractical. It is therefore evident that another method of increasing the sensitivity of the process is needed.

Berg in experimenting with relatively dry gelatin surrounding the grains of a photographic emulsion, found that the gelatin was inefficient in accepting released bromine but the mere moistening of the layer or the addition of a halogen acceptor improved the print out sensitivity.[13.]

In 1936, T. Slater-Price suggested that the mechanism of halogen acceptance by gelatin is dependent upon the hydrolysis of molecular bromine to form hypobromite ions which react with the gelatin.[14.]

The case for the bromogelatin complex suggested by Slater-Price was supported by further work from Hamilton, Hamm and Brady.[15.] Simultaneous pulses of light and voltage were used to study the motion of the electrons and holes in silver halide crystals. They showed that positive holes are mobile at the print out level of exposure and may react with gelatin. Electron micrograms of a specimen of a primitive course grained emulsion with inert gelatin showed a diffuse cloud of what was thought to be bromogelatin resulting from the pulsed exposure when positive holes displaced bromine atoms, some of which combined with the gelatin.

Another study by Arens and Eiserbech, published in 1957, showed that for print-out silver formation in the photographic layer, desensitization occurs by heating at $80^{0}C$ for 90 to 120 minutes. These effects were attributed to loss of water during heating with the resulting loss of ability of the gelatin to accept halogens. The storage of the material in a dessicator over water for one hour was sufficient to restore the loss sensitivity.[16.]

Procedure

Du Pont Lino-Writ 5 MRK 010 Direct Writing Paper (type W-thin weight) was cut into strips and placed in a light tight box. The paper was handled under darkroom conditions using a Kodak OC safelight not less than three feet away from the material. A Kodak No. 1A photographic step tablet was calibrated using a Welsh Densichron and positioned over the exposing plane of an Edgerton, No explanation why this was used Germeshausen and Grier Mark VI sensitometer. Exposure values for the sensitometer were taken from the instruction manual and were believed not have differed from a previous calibration.[17] An optimum sensitometric exposure was obtained from a series of tests and remained constant through out the experiment.[18] Four amplification intensities of 50, 75, 100, and 150 foot candles and two exposure times of 15 and 30 minutes were run with moistened and unmoistened paper.

A Doxor model P 2324 fluorescent lamp with one 15 watt Silvania "Cool White" fluorescent tube was used as the amplification light source.

A Photovolt foot candle meter was placed in the center of a 12 x 8 inch area and all readings for the intensity of the amplification exposure were made from this position. Readings were taken at all corners of the exposing area for each level of illumination.[19] The height of the lamp was adjusted to give the desired level of illumination.

A reference strip receiving no moisture was run at all levels of amplification intensity and time. This could be compared to strips run under similar conditions but with moisture added.

In the experiments where strips were to be moistened , sheets of Dow 'Handi Wrap' (a clear palstic wrapping material) were cut and placed flat on a table. The sensitometric strips were placed in the center of the sheet, moistened and wrapped up to prevent evaporation.

The absorbtion characteristics of the 'Handi Wrap' were obtained using a Beckman Model B spectrophotometer.[20.]

Distilled water was placed in a stainless steel tray to about a depth of about $\frac{1}{4}$ inch. A clean cellulose sponge was placed in the water, lifted, out, and allowed to drain. The sponge was placed down and drawn evenly over the strip. Immediately the 'Handi Wrap' was folded over the strip so that the emulsion side was covered by a single layer which was free of wrinkles. The moistened strips were dried in air before being placed in light tight bags to be read.

A latent image fading test was run because the strips could not be evaluated at once. Two sets of strips were exposed at the same time. One set was densitometered 15 minutes after exposure and the other eight days later.[21.]

A Macbeth model RD-100 reflection densitometer, modified with a Kodak wratten No. 25 filter placed over the light housing to prevent fog, was used to measure the reflection densities. Using no filter, the densitometer was calibrated with the Macbeth standard balck and white check ~~plack~~ plaque. After calibration, the No. 25 filter was attached to the light housing with 'Scotch' tape and a density of 0.80 was taken as the zero position.

The densities were plotted on D Log E curves using an expanded ordinate scale in order to separate curves which were extremely close to each other. From the curves a speed corresponding to the reciprocal of the exposure at a density of 0.05 above base plus fog was calculated.[22] Gamma was read directly from the curves with the aid of a Kodak model C-2 gradient meter. The net density was obtained by subtracting base plus fog from the maximum density.

Apparent differences between grand average values for the water and no water cases are compared by a t test to see if the difference are real. For a given parameter the variability in the data for the water and no water cases are compared through an F test for a significant difference. If the difference is significant the sources of variation contributing to the variability of water data will be determined by an analysis of variance. For additional information the variability in the data for the three positions of moisture addition were compared by an F test. Confidence intervals were placed on all mean values as well as the difference between means.

THE VALUES OF THE PARAMETERS FOR ALL COMBINATIONS OF I, T, P.

NO WATER ADDED								
tensity (Ft CD)	50		75		100		150	
iME (sec)	15	30	15	30	15	30	15	30
SPEED	.289	.186	.115	.102	.132	.100	.125	.079
	.173	.229	.115	.132	.120	.100	.115	.087
	.191	.191	.120	.131	.100	.118	.115	.076
GAMMA	.58	.60	.54	.52	.53	.55	.57	.59
	.60	.60	.57	.57	.57	.56	.60	.54
	.59	.60	.57	.59	.56	.56	.59	.55
NET DENSITY	.50	.55	.47	.49	.48	.46	.43	.45
	.50	.55	.47	.49	.46	.46	.46	.43
	.53	.57	.47	.49	.46	.47	.47	.44

H_2O ADDED BEFORE SENSI. EXPOSURE								
tensity (Ft CD)	50		75		100		150	
iME (sec)	15	30	15	30	15	30	15	30
SPEED	.080	.126	.115	.069	.091	.126	.079	.082
	.120	.120	—	.158	.080	.055	.081	.100
	.069	.075	.126	.063	.094	.063	.079	.053
GAMMA	.48	.54	.56	.62	.59	.58	.65	.54
	.52	.54	—	.54	.62	.55	.56	.54
	.45	.52	.54	.64	.55	.57	.63	.59
NET DENSITY	.40	.46	.46	.47	.45	.50	.50	.42
	.39	.45	—	.47	.45	.44	.50	.42
	.38	.46	.48	.47	.46	.45	.48	.42

H_2O ADDED BEFORE AMPLIF. EXPOSURE								
tensity (Ft CD)	50		75		100		150	
iME (sec)	15	30	15	30	15	30	15	30
SPEED	.174	.158	.092	.100	.132	.100	.079	.059
	.153	.169	.093	.100	.129	.103	.079	.060
	.187	.132	.105	.105	.120	.100	.087	.063
GAMMA	.61	.66	.64	.58	.54	.57	.65	.56
	.62	.68	.65	.62	.55	.54	.63	.59
	.60	.67	.67	.59	.56	.57	.62	.57
NET DENSITY	.52	.52	.53	.50	.46	.46	.49	.46
	.52	.51	.52	.49	.50	.48	.47	.46
	.54	.54	.49	.49	.49	.49	.49	.46

H_2O ADDED BEFORE BOTH EXPOSURES								
tensity (Ft CD)	50		75		100		150	
iME (sec)	15	30	15	30	15	30	15	30
SPEED	.126	.087	.050	.110	.093	.093	.090	.079
	.126	.115	.040	.138	.105	.120	.091	.079
	.144	.085	.126	.089	.120	.115	.076	.138
GAMMA	.57	.62	.55	.59	.63	.56	.59	.53
	.63	.57	.57	.59	.58	.55	.59	.58
	.57	.64	.58	.59	.58	.56	.57	.54
NET DENSITY	.48	.50	.50	.50	.50	.50	.47	.49
	.50	.50	.50	.52	.52	.51	.48	.46
	.51	.52	.50	.52	.51	.50	.48	.47

OF GRAND AND INDIVIDUAL MEAN VALUES

Code: X_w= Grand average for all water values.
Xnw=Grand average for all non-watered values.
Xbs=Grand average for all strips watered before Sensi sensitometric exposure.
Xba=Grand average for all strips watered before amplification exposure.
Xbb=Grand average for all strips watered before both sensitometric and amplification exposure.

Lino-Writ — An .05 level of significance was use used. — Polycontrast

	Lino-Writ Xw	Xnw	Xbs	Xba	Xbb	Xw-Xnw	Polycontrast Xw	Xnw
SPEED	.102 ± .00761	.135 ± .0204	.0915 ± .0149	.112 ± .0154	.101 ± .0113	.033 ± .0172	.235 ± .00297	.231 ± .00568
GAMMA	.582 ± .00956	.570 ± .0318	.562 ± .0193	.602 ± .0167	~~.455 ± .00504~~ .580 ± .009	.012 ± .0173	—	—
NET DENSITY	.50 ± .00786	.48 ± .0142	.45 ± .0148	.49 ± .0111	.50 ± .00727	.02 ± .0157	1.92 ± .00176	2.02 ± .00314

SUMMARY OF VARIANCE AND STANDARD DEVIATIONS
Code: same as for mean values.
An .05 level of significance was used.

	s^2w	s_w	s^2nw	snw	s^2bs	sbs	s^2ba	s_{ba}	s^2bb	sbb
SPEED	.00104	.0322	.00236	.0486	.00117	.0344	.0013	.0362	.000718	.0267
GAMMA	.00163	.0405	.00057	.0758	.00203	.0451	.00166	.0396	.0159	.127
NET DENSITY	.00109	.0332	.00113	.0338	.00112	.0336	.000687	.0263	.00030	.0173

SUMMARY OF SIGNIFICANCE TESTS
Code: same as for mean values.

	Lino-Writ Xw-Xnw	Xbs vs Xba	Xbb vs Xba	Xbb vs Xbs	s^2w vs s^2nw	s2bs vs s^2ba	s^2bb vs s^2ba	s^2bb vs s^2bs	Polycontrast Xw-Xnw		Comments
SPEED	S	N.S	N.S.	N.S.	S	N.S.	N.S.	N.S.	N.S		$s^2_{nw} > s^2_w$ $\bar{X}_{nw} > \bar{X}_w$
GAMMA	N.S.	S	S	S	S	N.S.	S	S	—		$\bar{X}_w > \bar{X}_{nw}$ $s^2_w > s^2_w$
NET DENSITY	S	S	N.S.	S	N.S.	N.S.	S	S	N.S.		$\bar{X}_w > \bar{X}_{nw}$ $s^2_{nw} > s^2_w$

An .05 level of significance was used.
S= significance NS= no significance

GRAND ANOVA TABLE FOR SPEED, GAMMA AND ~~NET~~ DENSITY

SOURCE	S.S.	D.F.	M.S.	F	S.S.	D.F.	M.S.	F	S.S.	D.F.	M.S.	F
		SPEED				GAMMA				NET DENSITY		
P	.00543	2	.00271	3.857 *	.01929	2	.00964	13.9710 *	.00034	2	.00017	.894737 N.S.
I	.01765	3	.00588	8.400 *	.00391	3	.00130	1.88405 N.S.	.00009	3	.00003	.157895 N.S.
T	.00072	1	.00072	1.029 N.S.	.00011	1	.00011	.15942 N.S.	.00003	1	.00003	.157895 N.S.
PI	.02308	6	.00384	5.486 *	.02320	6	.00386	5.59420 *	.00043	6	.00007	.368421 N.S.
PT	.00615	2	.00307	4.386 *	.01940	2	.00970	14.05797 *	.00037	2	.00019	.947360 N.S.
IT	.01837	3	.00612	8.7429 *	.00402	3	.00134	1.94202 N.S.	.00012	3	.00004	.210526 N.S.
IPT	.66194	6	.11032	157.6 *	.02800	6	.00466	6.75362 *	.06669	6	.011115	58.5263 *
ERROR	.03320	47	.00070		.03260	47	.00069		.00910	47	.000194	
TOTAL	.76654	70	.01095		.13053	70			.07780	70		

Conclusions:

by 25% at 95% confidence, comparing grand average for no water and all positions of water addition.

I. Speed

1) Water addition reduces threshold speed for lino-writ paper

2) Amplification intensity makes a difference Anova indicates that it is significant after in speed differences

23.

3) The position of moisture addition makes no difference

4) Interaction between position and intensity, position and time, intensity and time and a triple order interaction between intensity, position and time make a difference.

5) Intensity and time of amplification exposure alone makes no difference

6) Water addition has no effect on the threshold speed of Polycontrast paper with development

II. Gamma

1) Water addition does not effect the gamma of lino-writ paper

2) " " " " " " " " Polycontrast paper. with development

III. Net Density

1) Water addition increases net density. No change in scale observed Possible change of shape.

2) An interaction between intensity, position and time of amplification make a difference.

3) ~~The lowest value of net density occured with~~ Water addition prior to sensitometric exposure gave lowest average net density of the three positions of water addition

Discussion of Results

1) Contrary to what was expected from the literature there was a decrease in the threshold speed when water was added. This might have been due to the possibility of a highly doctored emulsion.

2) The amplification exposure for this paper is analogous to development for conventional materials. Since gamma is greatly influenced by amplification exposure time, then if time is a significant source of variation then a difference in observed values of gamma might be expected.

Development was essentially complete in 15 min since there was no [illegible]

The fact that time was not significant source may possibly be the reason why no difference in gamma was found when moisture was added.

3) Contrary to what was expected from the speed decrease by water addition, the net density increased when water was added. This might be explained by the relatively large value of the error term in the analysis of variance.

APPENDIX

1. The EG & G Mark VI sensitometer was calibrated in the School of Photography of the Rochester Institute of Technology.

2. At a given level of amplification exposure intensity, a series of 2 sensitometric exposures were run. The first was made by using an exposure of 7000 mcs. This resulted in a visually gross overexposure. Therefore the second member of the series was made using a time of 1/1000 sec. and a 1/100 sec. attenuator equivalent to a 1.0 neutral density was placed over the source. The resulting exposure of 700 mcs proved visually to give a good exposure and was therefore adopted as a standard.

3. The meter readings showed little difference between the illumination at the edges and at the center. The analysis of variance for each of the three parameters showed very small error terms and therefore tends to support this belief.

4. The following table shows the result of the spectrophotometric analysis:

* Wavelength	Transmission
335	81
350	84
375	86
400	87

5. A visual comparison of the curves as well as the data showed almost no difference between the two. As a precaution however, no strip was densitometered more than two days after exposure.

* Wavelength measured in millimicrons.

FOOTNOTES

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3. H. Luppo-Cramer, Phot. Korr., Vol. 72, 1936, p. 1
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5. W.F. Berg, A. Marriage, and G.W.W. Stevens, Photographic Journal, Vol. 86B, 1946, p. 1052
6. R.V. Dyba, and T.D. Smith, Photographic Engineering, Vol. 7, 1956, p. 98.
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11. Hunt, Op. Cit., p. 107
12. J.H. Jacobs, Photographic Science and Engineering, Vol. 5, 1961, p. 1.
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17. See 1) of appendix
18. " 2) " "
19. " 3) " "
20. " 4) " "
21. " 5) " "

FOOTNOTES

22. Ira B. Current, "Sensitometry of High-Speed Print Out Papers," Photographic Science and Engineering, Vol. 7, 1963, p. 105.

23. The Position of moisture addition makes no difference at a significance level of .025. It should be noted however that at a confidence level of .095 position is just barely significant.